

PHYSIOLOGICAL ASSESSMENT AND VALIDATION OF PERSONAL PROTECTIVE ENSEMBLES TOTAL HEAT LOSS

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Background

- The ability of personal protective ensembles (PPE) (Fig.1) to allow transfer of heat and water vapor out of the ensemble to the environment is measured by the bench scale Total Heat Loss (THL) test on a composite swatch of ensemble material.
- Manufacturers of PPE and independent labs test the heat loss characteristics of PPE materials on a THL apparatus (Fig. 2), assigning a THL number to the fabric.
- The relationship between the THL number and the heat loss from the body through the garment to the environment is not totally understood across all areas of first responders' PPE.
- This project will determine if a relationship exists between the THL value and the physiological response to wearing PPE, thus providing a sound physiological basis for setting THL values in current and future PPE performance standards.

Objective

Understand the relationship between THL values and human subject physiological variables obtained while wearing PPE constructed of the same composites across four separate THL ranges.

Proposed Technical Approach

- Three year project consisting of three phases of experiments to be performed using the guarded sweating hot plate (used to obtain THL), thermal manikin, and human subjects.

Phase 1: Build a prototype PPE using the same design and different materials (with different THL values) and test on a thermal manikin and human subjects.

Phase 2: Test a representative set of commonly available PPE across four separate THL ranges on human subjects.

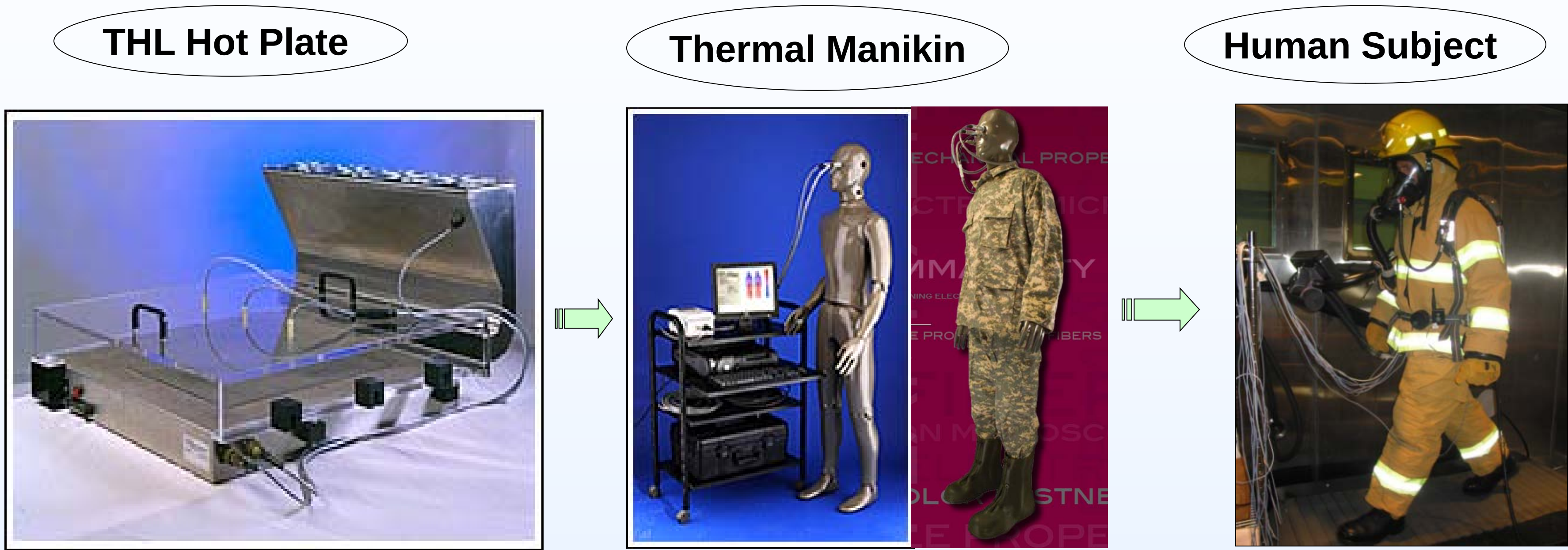
Phase 3: Evaluate the impact of reinforcements, pockets, visibility marking, linings, and other additional layers on the breathability of the garment through human subjects testing.

- Subjects:**
 - 12 healthy individuals will be recruited for the project
 - They will be heat acclimatized (HA)

- Environmental conditions:**
 - Upon completion of HA training sessions, subjects will participate in the PPE testing. The methodology that will be used for the PPE testing will follow the ASTM F1868-02 parts D and E as follows:
 - Ambient temperature: 20°C, relative humidity: 50% (ASTM F1868, part D)
 - Ambient temperature: 35°C, relative humidity: 50% (ASTM F1868, part E)



Figure 1: NFPA 1994 Class 3 Ensemble
Courtesy of Blauer



Advantages	Reproducible results (High reliability)	Reproducible results (High reliability)	Realistic values (High validity)
Disadvantages	Non- realistic values (Low validity)	Non- realistic values (Low validity)	Individual differences, circadian rhythm, fatigue, diet, activity, etc. (Low reliability)

Figure 2. Schematic of Technical Approach; photos courtesy of MTNW and Philadelphia University

Measurements:

- Core, skin, and microclimate temperatures (Fig.3)
- Energy expenditure [oxygen consumption (VO_2) and respiratory exchange ratio (RER)]
- Heat flux (HF), heart rate (HR), sweat rate (SR)
- Blood lactate and serum osmolality
- Subjective perceptions (Ratings of Perceived Exertion (RPE), and Visual Analog Scales (VAS) for comfort and heat perception)

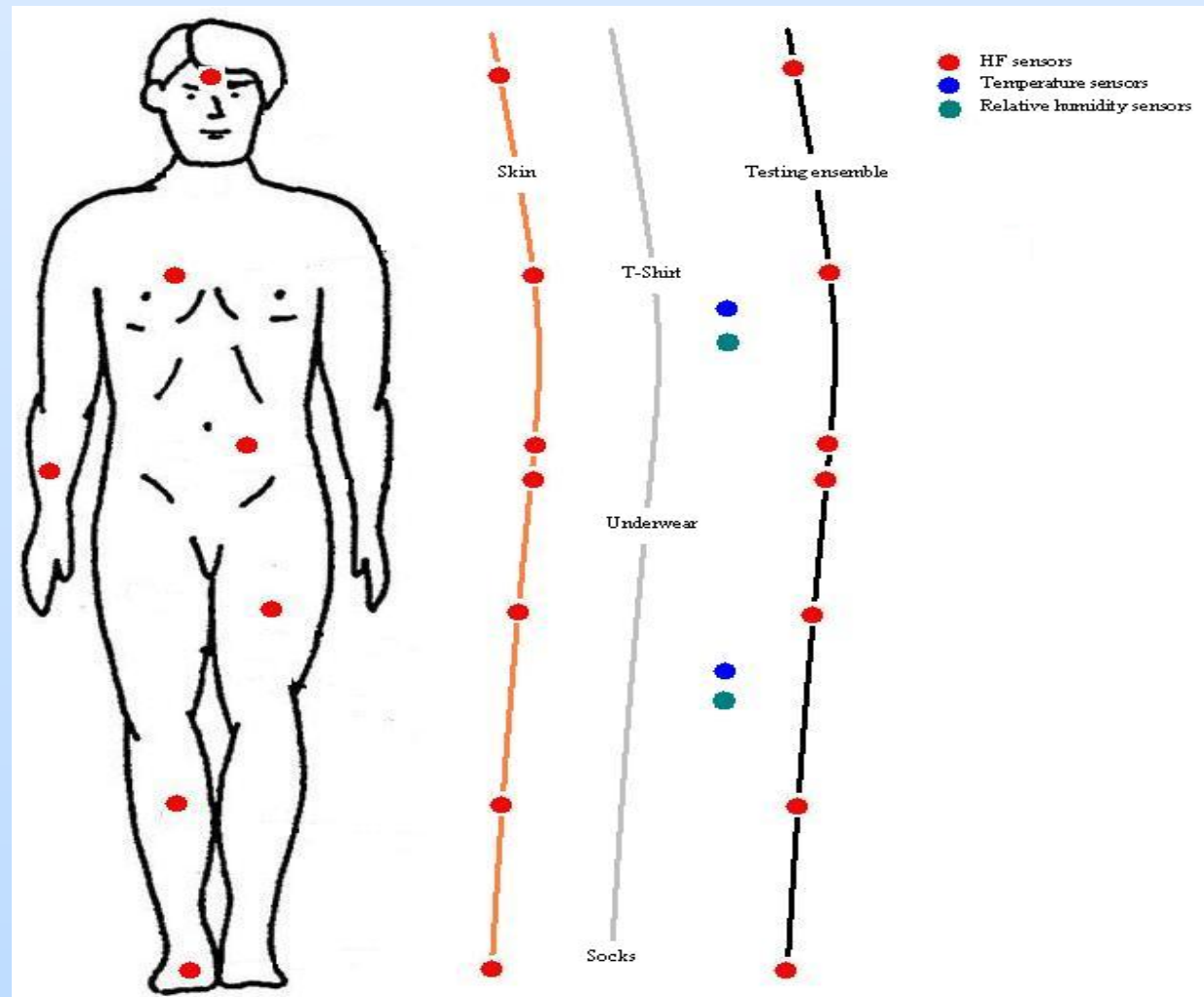


Figure 3. Diagram of sensor placement.

Data/Statistical Analysis:

- Various physiological data including Tcore, Tskin, HR, BP, and SR will be measured and recorded by data acquisition software. Subjective ratings: VAS and RPE will be measured for pre and post test and every 10 minutes during a test. Environmental chamber conditions: ambient temperature and relative humidity will be recorded. Microclimate conditions: temperature and humidity levels inside the protective ensemble will be constantly monitored.
- Each variable measured will be presented as a mean and standard deviation for each subject and protective ensemble with a different THL value for the two environmental chamber conditions. To investigate effects and interactions of THL values on physiological outcomes, a repeated measures analysis of variance (ANOVA) will be used. PPE (4) and chamber conditions (2) will be designated as independent variables, and physiological outcomes will be designated as dependent variables.

Disclaimer: The findings and conclusions of this poster have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Expected Results and Significance

- Despite a voluminous amount of research on THL values of functional fabrics used to manufacture PPE and human physiological responses in protective clothing and ensembles, there are few studies that have focused on examining how different THL values influence actual physiological responses by comparing different types of PPE.
- These findings will provide a rational basis for the selection of criteria for the PPE intended for use in different operational and hazardous situations.
- Research will provide a sound physiological basis for setting THL values in current and future PPE performance standards.
- Furthermore, the results of this research may also be used to modify and develop new test methods or performance requirements by ASTM, ISO, or NFPA for measuring THL in PPE.

Timeline

FY10 (Oct 2009- Sept 2010)	Develop human subject test plan and complete external peer-review and NIOSH HSRB approval	June 2010
	Contract THL testing at an independent test laboratory	Sept 2010
	Select ensembles, recruit subjects, and start data collection	Dec 2010
FY11 (Oct 2010- Sept 2011)	Complete second and third phases of human subject testing	June 2011
	Analysis of results	Sept 2011
FY12 (Oct 2011- Sept 2012)	Produce final report	Sept 2012
	Prepare manuscripts to submit to peer-reviewed journals	Sept 2012
	Recommend appropriate THL criteria for revision of applicable protective ensemble standards	Sept 2012

Expected Outputs and Outcomes

- Submission of manuscripts to peer-reviewed journals.
- Presentation of the physiological performance models and recommendations on establishment of THL criteria with a physiological basis for use to the NFPA Technical Committees (1994, 1971, 1977, 1951, 1992) and to the ASTM F23 Committee.
- Results from this study will be used to support revisions or updates to all applicable NFPA Standards and ASTM Test methods.

Stakeholders and Partners

- Emergency Responders
- Garments and Materials Manufacturers
- Test Laboratories
- NFPA
- ASTM
- Underwriters Laboratories (UL)